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SOME PROBLEMS ENCOUNTERED IN THE SAMPLING OF PROCESSED FRUIT AND VEGETABLE PRODUCTS

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The topic under discussion this evening is one which is extensive in scope and application - one which has significant importance in the many phases of the food processing industry.

Needless to say, industry and management are becoming increasingly aware of the effectiveness with which modern statistical methods are utilized in controlling and maintaining quality levels. Likewise, we in the Fruit and Vegetable Division of the Agricultural Marketing Service recognize the merit of a scientific approach to the problem of sampling. However, we encounter numerous practical difficulties in carrying out any sampling procedure. The value of our service in the marketing of food products often depends as much upon its practicability and economy as upon its level of assurance. Therefore, I welcome this opportunity to present to you some of the problems encountered in the sampling of processed fruit and vegetable products.

One of the primary functions of the Agricultural Marketing Service is the inspection and certification of the <u>class</u>, <u>quality</u> and <u>condition</u> of agricultural commodities. Since my work deals with the inspection and certification of processed fruits and vegetables, and related processed products, my comments will be made with these products in mind. The inspection service which I represent is directed to the end that these fruit and vegetable products may be marketed to the best advantage, that trading may

be facilitated, and that consumers may be able to obtain the quality of product which they desire. Anyone familiar with today's food processing industry can readily appreciate the enormous quantity and variety of merchandise packed each year. This mass of produce represents a large potential field requiring a measurement of quality and research in the development and investigation of methods and tests to measure important quality factors. To satisfy this demand, the services of our Branch are used extensively by both Industry and Government. Therefore, problems incident to Sampling and Inspection are by no means restricted to a few commodities, a limited quantity, or any particular geographical location.

Evaluation of the characteristics of a given lot of merchandise and determination of quality must necessarily be predicated upon data obtained from samples. The precision with which the overall quality of the lot is established depends upon the adequacy of the sample - how many containers are drawn and how representative they are. There are significant economic limitations with respect to the size of sample that can be taken for inspection purposes of processed fruits and vegetables. The extent to which time, effort and money can be expended in increasing sample size in order to reduce the effect of chance errors or the so called "accidental sample" has a definite bearing on how general our service may be utilized by the Industry.

At this point I think it appropriate that, for a moment, we divert our thinking to the mass of essential data that is available to the technician once the sample has been selected and evaluated. If the method of sampling is unbiased, then, since we are dealing with inanimate material our observations and measurements are not subject to the errors or opinions that might be experienced when dealing with a population of human beings. Accuracy in the measurements of character or quality of the sample rests largely with the

ability of the technician to properly evaluate the attributes which serve to classify the sample as to class or rank. The essential data obtained from such analyses is recorded for subsequent evaluation. What then are some of these properties or attributes possessed by the sample which individually and collectively indicate the overall quality and degree of excellence of the merchandise which it represents?

Let me enumerate some of these increments or characteristics by classifying them catagorically in a sequence generally observed in normal inspection procedure:

(1) Primary Containers - this will include information with respect to size and type of container; type of closure; protective coatings or linings on internal or external surfaces; condition of containers with respect to rust or corrosion, dents, swells, serious panels; cleanliness of containers and freedom from smeared syrup or residual vegetable material; labels; suitability of overwrap; code marks or other identification.

(2) Identity of Product as evidenced not only by compliance with existing standards or regulations but also by such characteristics as Style; Type; Size or Color designations; Variety; Count and Ingredient Proportion.

(3) Measurements of Non-Quality Factors - such as vacuum readings; net weights; drained weights; fill of container; density of packing media; salt content; total acidity; sulphur dioxide content; moisture content; refractive index readings, etc.

(4) Evaluation of Quality Factors - those inherent properties which determine the relative degree of excellence of such product and include the effects of preparation and processing, with or

without packing media or added ingredients. Factors of quality are evaluated individually and may be given a numerical rating to indicate the degree of excellence or perfection. The overall rank or class of the product is determined by consideration of quality factors or attributes which individually or collectively affect the acceptability of the product. Examples of such attributes are factors such as Color; Defects; Uniformity of Size; Consistency; Finish; Maturity; Tenderness; Texture; Character and Flavor.

(5) Wholesomeness or Soundness of Product - is there any material present that renders the product either deleterious to health or unfit for consumption? To determine this may require micro-analytical analyses for extraneous materials such as mold, rot infestation of various types, sand or grit. It may include yeast or bacterial counts. Attention is also directed to the condition of the product to determine whether it has deteriorated in any respect due either to bacterial decomposition or chemical reaction to the extent that the edibility is seriously affected or the product rendered unfit for human consumption.

From the foregoing discussion and enumeration it can be seen that during normal inspection many factors are measured, which when appraised, establish the characteristic rank or degree of excellence of our sample. The accuracy with which such data reflects the true quality and condition of the lot is largely dependent upon the adequacy of the sample, as we have previously mentioned.

Before discussing our problems let us first consider a few broad industry problems.

We must recognize the wide variation associated with fruit and vegetable products even when processed under good commercial practices. The packer is obliged to accept a raw product endowed by nature not only with many desirable attributes but also with characteristics or defects that are undesirable or highly objectionable. Through a series of operations which may consist of grading, sorting, washing, draining, blanching, trimming, segregation, brining, syruping, etc., he attempts to eliminate the undesirable components of the raw product, enhance the desirable characteristics and effect a reasonable degree of uniformity from container to container. It is impossible to pack within rigid control limits that might be applicable to many manufactured products. Marked variations are not uncommon from commodity to commodity, season to season, packer to packer, and even within a single pack.

Now let us explore some of the problems encountered in the sampling of processed fruit and vegetable products;

The initial problem deals with the historical background of the lot. What pertinent information is available to the inspector to guide him in his selection of a sample? In many instances the inspector has a very limited knowledge of the nature of the stack of merchandise which confronts him in the warehouse. He will be provided with certain information such as commodity, container size, number of containers in the lot, warehouse location, and possibly date of pack. In some instances he will have access to a record of the code marks present in the lot, the number of containers represented by each code mark and possibly the relative location of each mark within the stack. The degree of variability of quality within the lot cannot be ascertained by a visual examination of the closed container. The effects of preparation and processing will not be apparent to the sampler, except in those instances in which swelled containers may have developed. Generally, the position within the stack cannot be associated with the sequence of processing. A lot may consist of a segment of a day's pack, an entire day's run,

portions of several day's pack, or various combinations thereof. The sampler will attempt to draw containers which are as nearly random as possible. If adequate information regarding the lot is available, samples are usually selected, insofar as practical, so as to represent each identifying mark and in proportion to the quantity represented by such code mark.

The aforementioned problems are very real when dealing with the type of inspection commonly referred to as "Lot Inspection". However, the Department has a type of service available to the packer which is known as "Continuous Inspection". As the name denotes, under this type of service an inspector is present during the entire period the plant is in operation. He is able to observe the various steps in the process from the time the raw material is received until it has been warehoused as a finished product. It is obvious that under such an arrangement the inspector has a definite advantage in that he observes the quality going over the line at all times and is able to identify such quality with a definite segment of the lot when finally warehoused. Pack records compiled during the plant operation not only serve as a form of quality control for the packer but also provides excellent data in predicting the final grade of the lot.

A second and most difficult problem to cope with is the <u>accessibility</u> of the lot for random sampling. Warehouse space is generally at a premium and merchandise is normally stacked in such manner as to efficiently utilize available space rather than facilitate sampling. Consequently, merchandise is frequently stacked many cases high with no intervening space between rows. It is not uncommon to encounter situations in which access to the lot is restricted to the top cases of each stack and the face of the first stack in the row. The inspector must now make a decision between declining the inspection because the lot is inaccessible or requesting that the lot be physically broken down to the extent that random samples may be drawn. If the warehouse

does not have a palletized operation, a lot of time and physical effort is expended in moving cases and digging down into stacks to obtain samples. Here again the value of continuous inspection is emphasized. The inspector assigned to the plant can draw some containers from the processing line as well as from the stacks as they are being assembled in the warehouse.

A third problem and one which is closely identified with Frozen Fruits is the sampling of bulk containers. A large portion of frozen fruits and berries are packed in institutional sized containers ranging from 25 pound cans up to 50 gallon barrels. Anyone who has attempted to drawn a large number of bulk containers, thaw them to the extent that the contents may be readily separated and then examine the contents in detail recognized that it is not only quite impractical, but also economically prohibitive as inspection destroys the market value of the sample. This problem has been overcome to a large extent by obtaining sub-samples from the containers. If the product is one which is homogeneous in character, we may accept the sub-sample with little reservation. However, some products such as frozen fruits, present additional problems with respect to the uniformity of the contents within the container and the degree to which the physical characteristic of the product may be altered in securing the sub-sample. With respect to homogeneity, it is not uncommon to find that the fruit ingredient and the packing media are not uniformly distributed within the container. Often times the lower portion of the container is almost entirely packing media with very little fruit ingredient whereas the top of the container is practically all fruit. Likewise, some fruits tend to materially oxidize on the surface exposed to the atmosphere. Samples taken from the top of the container could be very misleading. The mechanics of obtaining a sub-sample varies with the nature of the product. I believe all are familiar with the trier or "Thief" used for sampling grain products and equally as suitable

for such staples as salt and sugar. Plastic or metal tubes and plungers are quite adequate for sampling bulk containers of products such as honey. Here again the frozen fruits and berries present the most difficulty. A sample should be selected so as to represent all portions of the container. This is best accomplished using a power driven sampling tube with teeth to facilitate cutting the material. Several cores may be taken so as to represent all portions of the containers. One notable drawback to such method is the fact that the cores are relatively small in diameter and tend to destroy the normal conformation of the fruit, particularly when the fruit is in large pieces such as halved peaches or quartered apples.

A fourth problem deals with the economic aspects of sampling and the disposition of the samples. What are the limitations imposed upon the size of the sample? As I pointed out in the opening paragraphs of this paper, the very nature of our inspection work demands detailed information from each sample. Many determinations and measurements are made to determine the quality and condition of each sample. This is not a case of a "go" or "no go" separation based on one or more quick objective tests. On the contrary, many of the measurements are detailed and time consuming. Consequently, the size of the sample must be trimmed to conform with the practical values derived from inspection. Another factor of significance is the destructive nature of inspection. Once the container has been opened and the contents examined, it no longer has market value. This is much more apparent when dealing with large containers and products that demand premium prices in the retail trade. Since the packer not only must furnish the samples without charge to the Government, as well as pay for the services of the inspector, it is obvious that the service would be prohibitive if certain limitations are not placed on sample size; and yet, the sample must be sufficiently large to reflect the quality of the lot with a reasonable amount of precision.

The fifth problem is one which is closely associated and integrated with some of the previously discussed problems. It has reference to a sampling plan which has enough flexibility to provide for a reasonable amount of adjustment with respect to commodity, container size and lot size. Some fruits and vegetables can be packed to much closer specifications than can others. Consequently, the end product reflects a greater degree of uniformity of quality than can be expected from another commodity. Improvement in canning technique and equipment tends to reduce error contributed by hand packing. Some products lend themselves more readily to mechanized packing than do others. Current regulations recognize differences in commodities and container size inasmuch as the minimum sampling rates are adjusted according to container size and groups of commodities. Present sampling plans are being studied with a view of improving them whenever it is found feasible to do so.

A final observation not only presents a problem in sampling but also represents a hazard in sampling and inspection. It concerns the possibility of a lot being sampled too soon after packing to the extent that equalization of product and packing media has not been sufficiently accomplished; likewise, incipient spoilage may not be detected if sufficient time has not elasped between packing and inspection to allow for incubation of spoilage organisms. Considerable amounts of merchandise are labeled off the line and shipped immediately. Circumstances may necessitate immediate inspection. This being the case, the inspection certificate must not be construed as a preservative. The chance that quality or condition may change is a risk the packer or buyer must assume.

The remainder of this paper will be devoted to an analysis of data compiled in an actual inspection problem. For this study we selected a lot of Canned Tomatoes which were sampled and inspected during the past season. The lot consisted of 3,000 cases each containing 6 No. 10 cans. The packer stated that it represented an entire day's production and that it was stacked in five accessible sub-lots arranged in a sequence approximately in order of the time of day the fruit was processed. His purpose in making a segregation into five sub-lots was to facilitate final stacking according to the grade assigned to each lot after official government inspection.

Figure A shows the general plan in which the merchandise was warehoused. For all practical purposes the sample selected can be considered truly random inasmuch as the manner of stacking made it possible to reach any case in the lot. According to the packer's records, Sub-lot 1 was processed during the first period of the day, Lots 2, 3, and 4 followed in sequence and Sub-lot 5 represents the final portion of the day's run. Each sub-lot consists of approximately 600 cases.

FIGURE A

SUB-LOTS

1	2	3	4	5
A1	A2	A3	A4	A5
B1	B2	B3	B4	B5
C1	C2	C3	C4	C5
D1	D2	D3	D4	D5
A1	A2	A3	A4	A5
B1	B2	B3	B4	B5
C1	C2	C3	C4	C5
D1	D2	D3	D4	D5
A1	A2	A3	A4	A5
B1	B2	B3	B4	B5
C1	C2	C3	C4	C5
D1	D2	D3	D4	D5

Treating the entire 3,000 cases as a single lot, the minimum sampling rate is 15 cans. However, since the packer desired that each sub-lot be inspected as a unit the sampling rate would be increased to a minimum of 6 cans per lot in order to apply limiting rules provided by the standards. For the purposes of this study the rate was increased to 12 cans per sub-lot or 60 cans for the entire lot. The lot was sampled in the following manner: Three systematic samples were drawn from each sub-lot, making a total of 15 cans for the overall lot. Each container so selected was identified with the letter "A" as well as a number to indicate the sub-lot from which it was drawn. In a similar manner three more replicates of 15 cans each were drawn from the lot. Each container was properly marked to identify it with a specific replicate (B, C or D) and also the corresponding sub-lot.

Summarizing the sampling, we have a total of 60 cans, divided into four replicates of 15 cans each, each can being identified not only with the proper replicate but also as a sub-lot. A total of 12 samples was selected from each of the five sub-lots.

The 60 samples were inspected for quality in accordance with the "United States Standards for Grades of Canned Tomatoes." I will not go into detail upon the manner in which each factor of grade was evaluated. However, let me mention that the final grade assigned to any container is based upon evaluation of the four quality factors - (1) Drained weight, (2) Color, (3) Absence of Defects and (4) Wholeness. Within each factor there are certain limiting rules which prevent a container that is particularly poor in some respect from being assigned a final grade that is inconsistent with the acceptability of such container. The data was recorded in such manner that each can could be identified with the proper replicate and sub-lot.

A summary of the examination is as follows:

(1) Replicate A - 12 cans Grade B
3 cans Grade C
Sub-lots - 1, 2 and 4 Grade B
3 and 5 Grade C

(2) Replicate B - 6 cans Grade B
8 cans Grade C
1 can Substandard

Sub-lots - 1 and 2 still consistently Grade B
Sub-lots 3 and 4 Grade C
Sub-lot 5 Substandard

(3) Replicate C - 11 cans Grade B
3 cans Grade C
1 can Substandard

Sub-lots - 1 and 2 still consistently Grade B
Sub-lot 4 shows improvement over replicate B as all cans were Grade B this time
Sub-lot 3 Grade C, account "Color".
Sub-lot 5 again Substandard account "Defects".

(4) Replicate D - 6 cans Grade B
8 cans Grade C
1 can Substandard

Sub-lots - 1 and 2 still Grade B, although 1 can of Lot 1 Grade C, account "defects".
Sub-lots 3 and 4 Grade C, account "color"
Sub-lot 5 again Substandard account "defects"

The results of the inspection were recapitulated by sub-lots taking into consideration the overall grade represented by the entire 12 containers identified with each specific lot. The results of this analysis appear in Table B which indicates the number of containers of each grade for each sub-lot and the grade of the Lot as a whole for each Sub-lot.

TABLE B

SUB-LOT	GRADE B	GRADE C	GRADE D	LOT AS A WHOLE
1	11 cans	1 can	0	B
2	11 cans	1 can	0	B
3	2 cans	10 cans	0	C
4	7 cans	5 cans	0	C
5	4 cans	5 cans	3 cans	D

In summarizing the results of this inspection we may draw the following conclusions based on samples drawn:

(1) The lot as a whole is significantly variable in quality, ranging from Grade B to Substandard

(2) Sub-lots 1 and 2 are consistently of higher quality and we would classify them as Grade B.

(3) Sub-lots 3 and 4 have a high percentage of Grade C containers and therefore they cannot be classified higher than Grade C.

(4) Sub-lot 5 is of definitely poorer quality and the number of containers that are Substandard make it necessary to classify it as Substandard lot.

The data compiled in this study was further evaluated by the Statistical Clearance Division, Agricultural Marketing Service, U. S. Department of Agriculture. Their findings are presented in the form of "analysis of variance tables" for the appropriate quality factors used in the inspection of Canned Tomatoes. Each table is supplemented with the "Duncan Test" to determine how each mean compares with the other mean.

Each table will be discussed separately but before doing so a general statement can be made. In each table the analysis of variance consists of five columns: Column one denotes the source of variation, the second column denotes the degree of freedom, the third column denotes the sum of squares, the fourth column denotes the mean square (obtained by dividing column 3 by 2) and the fifth column denotes the F ratio obtained by dividing the mean square for between sublots by the mean square for within sublots. If this ratio is greater than 2.54, an asterisk is used to denote there is a significant difference between the five sublot means at the 5 percent level. If the F ratio is greater than 3.68, two asterisks are used to denote significance at the one percent level. The 5 percent and one percent levels imply that only 5 percent, or one percent of the time, as the case may be, do we expect that we have made the wrong decision when we say there is a real difference between the sublot means. In brief, the analysis of variance tells us whether the two mean squares are really different or whether it is only ordinary random sampling that is causing the difference.

A 5 percent or 1 percent level analysis of variance F test only tells us whether the sub-lot means are unequal. When one finds that they are not equal, one can use a test such as the "Duncan Test" in order either to rank the means or to separate them into ranked groups of means. The sequence of operations involved in the test are not shown here but rather only the final results of the test. Below each table the means have been ranked and brackets used to indicate the results of the "Duncan Test".

TABLE I

Table I is the analysis on Absence of Defects. The analysis of variance tells us that the five sublot means are significantly different at the one percent level as is indicated by the double asterisk on F. The "Duncan Test" tells us that the mean for sublot 5 is significantly less than the other four sublots at the one percent level. And that sublot means 1, 2, 3, and 4 are not significantly different from each other.

Analysis of Variance - Absence of Defects

Source	d.f.	s.s.	m.s.	F
Between Sublots	4	575.93	143.98	7.44 **
Within Sublots	55	1064.00	19.35	
TOTAL	59	1639.93		

Results of "Duncan Test"

Sublots	(3)	(2)	(4)	(1)	(5)
Means	26.58	25.58	25.25	24.50	17.92

TABLE II

Table II is the analysis of Wholeness. The analysis of variance tells us that the 5 sublot means are significantly different at the 5 percent level as indicated by the single asterisk on F. The "Duncan Test" gives the same result as found in Table I, except the differences are significant at the 5 percent level.

Analysis of Variance - Wholeness

Source	d.f.	s.s.	m.s.	F
Between Sublots	4	6.43	1.608	3.62 *
Within Sublots	55	24.42	.444	
TOTAL	59	30.85		

Results of "Duncan Test"

Sublot	(1)	(3)	(2)	(4)	(5)
Means	15.83	15.75	15.67	15.58	14.92

TABLE III

Table III is the analysis of color. The analysis of variance says that there is a significant difference between the five sublot means at the one percent level. The Duncan Test reveals that sublot 3 is significantly lower than sublots 1, 2, 4, and 5, and that sublots 4 and 5 are also significantly lower than sublots 1 and 2; it also states that there is no significant difference between sublots 4 and 5.

Analysis of Variance - Color

Source	d.f.	s.s.	m.s.	F
Between Sublots	4	73.08	18.27	13.74 **
Within Sublots	55	73.10	1.33	
TOTAL	59	146.18		

Results of "Duncan Test"

Sublots	(2)	(1)	(5)	(4)	(3)
Means	24.42	24.33	23.08	22.83	21.42

TABLE IV

Table IV is the analysis of the Drained Weight. For the pruposes of this compar son we have used the actual weights as recorded in ounces rather than the USDA numerical score corresponding to a given weight. This is necessary in order to show variance since in USDA evaluation of the factor of drained weight only one score is assigned to the lot based on the average drained weight of all containers representing the lot. The analysis of variance says that there is no significant difference between the sublot means. The F ratio obtained was 2.43 which is just short of the 5 percent level of 2.54. It is quite possible that if more observations had been taken we would have obtained a significant difference. However, since the significant level of 5 percent was not obtained, no Duncan Test can be legitimately applied at the 5 percent level.

Analysis of Variance - Drained Weight

Source	d.f.	s.s.	m.s.	F
Between Sublots	4	66.86	16.72	2.43
Within Sublots	55	378.09	6.87	
TOTAL	59	444.95		

Results of "Duncan Test"

Sublots	(1)	(4)	(2)	(3)	(5)
Means	66.58	65.75	65.60	65.23	63.40

TABLE V

Table V contains the analysis of the Total Score which is the sum of all other factors including the numerical score for drained weight as assigned by the USDA Inspector. The analysis of variance says that there is a significant difference between the sublot means at the one percent level. The "Duncan Test" gives the same result as found for Table I, i.e., sublot 5 is significantly less than the other four lots at the one percent level.

Analysis of Variance - Total Score

Source	d.f.	s.s.	m.s.	F
Between Sublots	4	840.60	210.15	9.82*
Within Sublots	55	1177.00	21.40	
TOTAL	59	2017.60		

Results of "Duncan Test"

Sublots	(2)	(1)	(3)	(4)	(5)
Means	81.42	80.42	79.25	79.00	70.92

Here it is to be noted that the "Duncan Test" did not show significance between lots 1, 2, 3, and 4, although the USDA analyses classifies Lots 1 and 2 as Grade B and Lots 3 and 4 as Grade C. The reason for this is the fact that USDA grades are not assigned wholly on the basis of total score but also upon the effects of limiting rules with respect to the individual factors. In this respect Lots 3 and 4 were assigned a lower grade account Color. This is verified to a degree by Table III, in which the "Duncan Test" indicated that Lots 1 and 2 are significantly better than the other 3 lots.

Our somewaht cursory view of these tables may have left an impression somewhat at variance with our analyses of the lot based on USDA inspection procedure and assignment of grades to each lot. However, two points must be kept clearly in mind:

(1) It is quite possible to show statistically significant differences between sublots that do not differ sufficiently to fall into different grades; and

(2) Certain limiting rules that are observed in assigning a USDA grade have necessarily been ignored in the analysis of variance of quality scores.

Summarizing the tables, however, sublot 5 appeared significantly inferior to all other sublots on Absence of Defects, Wholeness and Total Score. Furthermore, it was inferior to Lots 1 and 2 on Color and scored lowest on Drained Weight, though not significantly so at the 5 percent level.

The failure of sublots 3 and 4 to show up generally in the tables as inferior to sublots 1 and 2 is at least partly due to the effects of the limiting rules applied by USDA in assigning grades as was noted earlier. The overall objective of the analyses was to demonstrate the need for stratification in the sampling of the 3,000 cases if considered as a single lot. This point is quite amply demonstrated by the genrally consistent significance between sublots.

In conclusion, let me summarize this discussion by again directing your attention to the primary objective of the inspection service with respect to the marketing of processed fruits and vegetables and the various factors which impose limitations on sampling. The Fruit and Vegetable Division of Agricultural Marketing Service has the responsibility of inspection and certification of fruits and vegetable products with respect to class, quality, and condition. Quality measurements cannot be made with the degree of accuracy applicable to a fabricated product engineered to precise specifications. The complex nature of the raw product, together with its many variable inherent characteristics, necessitates a system of quality evaluation that has a reasonable degree of flexibility. Recognizing that this variability exists in the finished product it is desirable to obtain numerous stratified samples for inspection purposes. In selecting random or stratified samples we are confronted with the reality that merchandise is not generally warehoused in a manner that makes all portions of the lot accessible. It is true that stacks can be broken down, and this is frequently done, but in many instances this can only be accomplished at a considerable cost - both in time and physical effort.

Inspection of processed products involves destructive sampling. It should also be borne in mind that we are classifying products into groupings that cover a rather broad range instead of categroies that are narrowed down to precise limits.

To be practical an inspection service for processed foods must be evaluated with respect to <u>cost</u> in terms of time involved, effort expended, value of samples destroyed and salary of inspector in relation to Industry requirements. Recognizing that our method is not perfect we are earnestly striving to improve our sampling procedure.